HARVESTING THE SKIES

Augmenting Rain through Cloud Seeding

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TEXAS DEPARTMENT OF LICENSING AND REGULATION (Austin)

For the
City of Wichita Falls
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Key Definitions

- ***Weather modification and control***

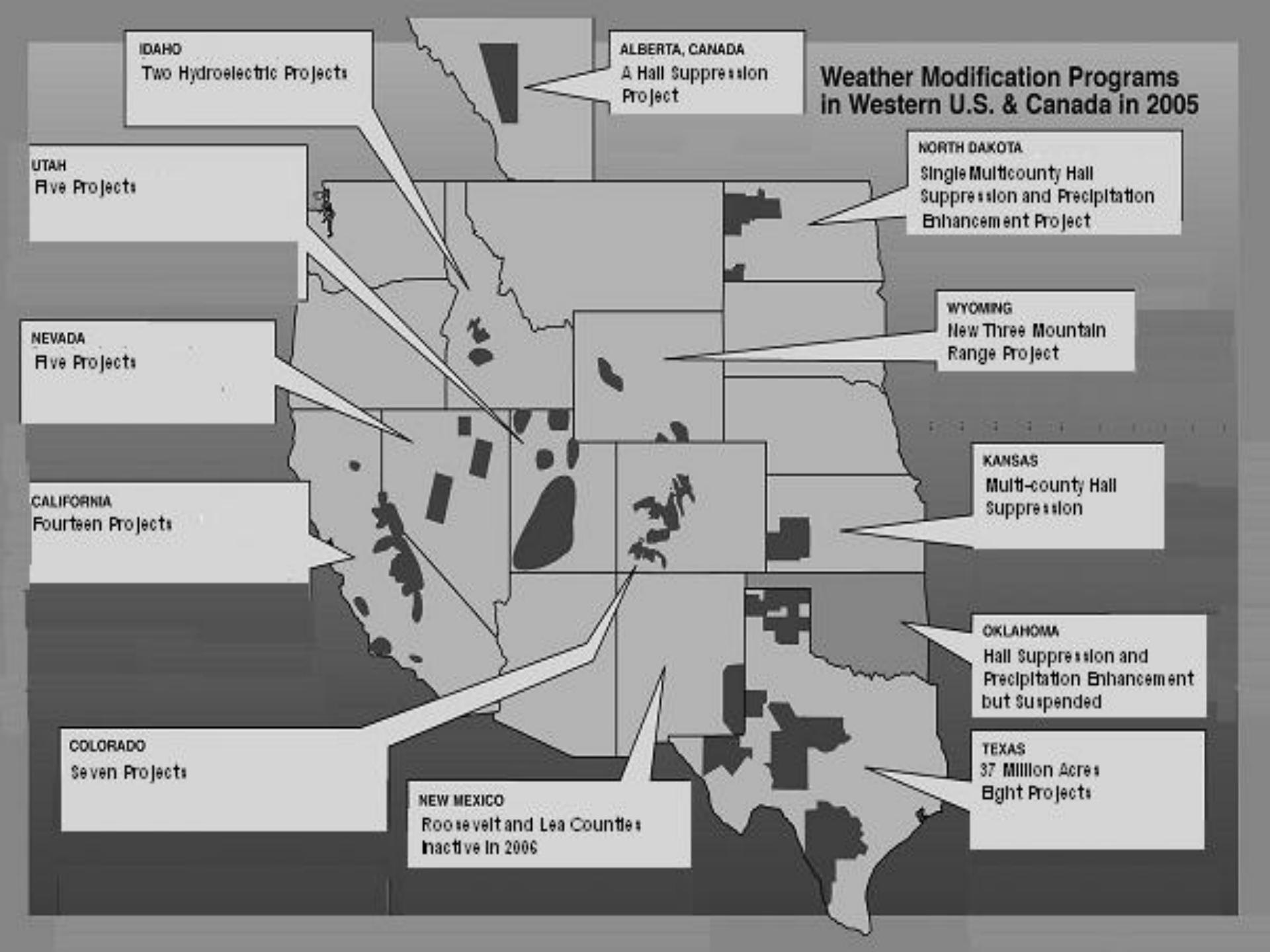
Changing or controlling,

or attempting to change or control,

by artificial methods (cloud seeding using aircraft)

the natural development

of atmospheric cloud forms or precipitation forms that occur in the troposphere


Weather Modification Programs in Western U.S. & Canada in 2005
IDAHO
Two Hydroelectric Projects
ALBERTA, CANADA
A Hail Suppression Project
NORTH DAKOTA
Single Multicounty Hail Suppression and Precipitation Enhancement Project
UTAH
Five Projects
WYOMING
New Three Mountain Range Project
NEVADA
Five Projects
KANSAS
Multi-county Hail Suppression
CALIFORNIA
Fourteen Projects
OKLAHOMA
Hail Suppression and Precipitation Enhancement but Suspended
COLORADO
Seven Projects
TEXAS
37 Million Acres
Eight Projects
NEW MEXICO
Roosevelt and Lea Counties
Inactive in 2006

TEXAS WEATHER MODIFICATION ACT
1967

Licenses and permits

Expertise of personnel in control and in charge

Technical merits of proposed projects: Specified *Target* and *Operational* Areas

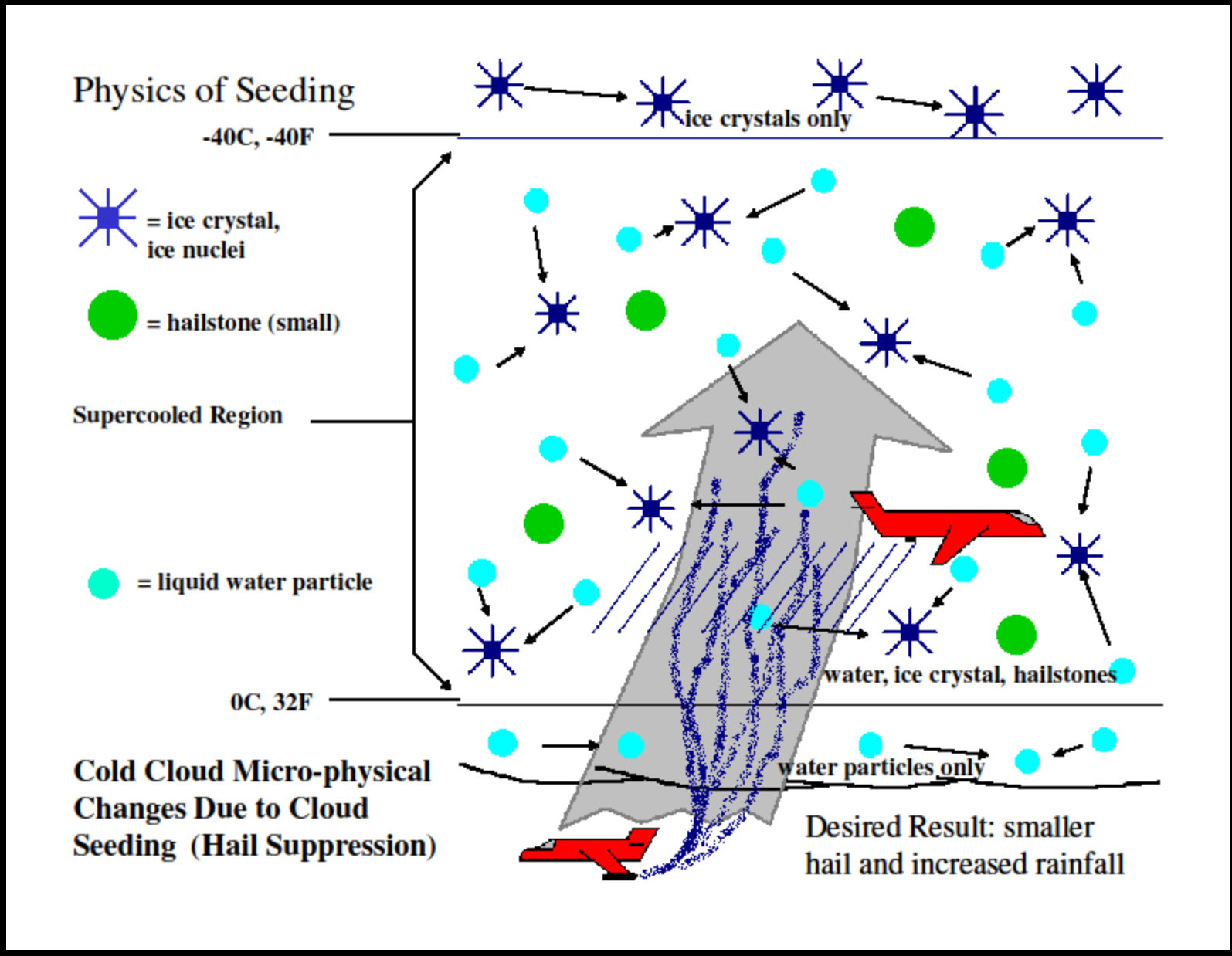
Exemptions

- R & D by state and federal institutions
- Laboratory research
- Emergency operations (fire, frost, sleet, fog)

Weather Modification Advisory Committee

Elections

Hail suppression activities only


Physics of Seeding
-40C, -40F
ice crystals only
= ice crystal, ice nuclei
= hailstone (small)
Supercooled Region
= liquid water particle
water, ice crystal, hailstones
0C, 32F
water particles only
Cold Cloud Micro-physical Changes Due to Cloud Seeding (Hail Suppression)
Desired Result: smaller hail and increased rainfall


N69538
Ejectable:
20 gram flare silver iodide
Burn in place:
40 gram flare silver iodide


ICE-3B

EARLY OPERATIONAL PROGRAMS

COLORADO RIVER MUNICIPAL WATER DISTRICT

Big Spring: Begun in 1971

Cloud base seeding (AgI) with aircraft
Target-control regressions analysis: 34 percent increase in rainfall in target vs. 13 percent in control
Cotton production up 48% in target vs. 8 percent in control
Downwind seeding effect: Rain increases up to 75 miles

CITY OF SAN ANGELO

Base seeding (AgI) in 1985-1989

Target-control regression analysis: 17 percent increase in rainfall in target (27 to 42% increase nearest reservoirs)

Focused RESEARCH

HIPLEX

High Plains Cooperative Program: USBR (1974-1980)

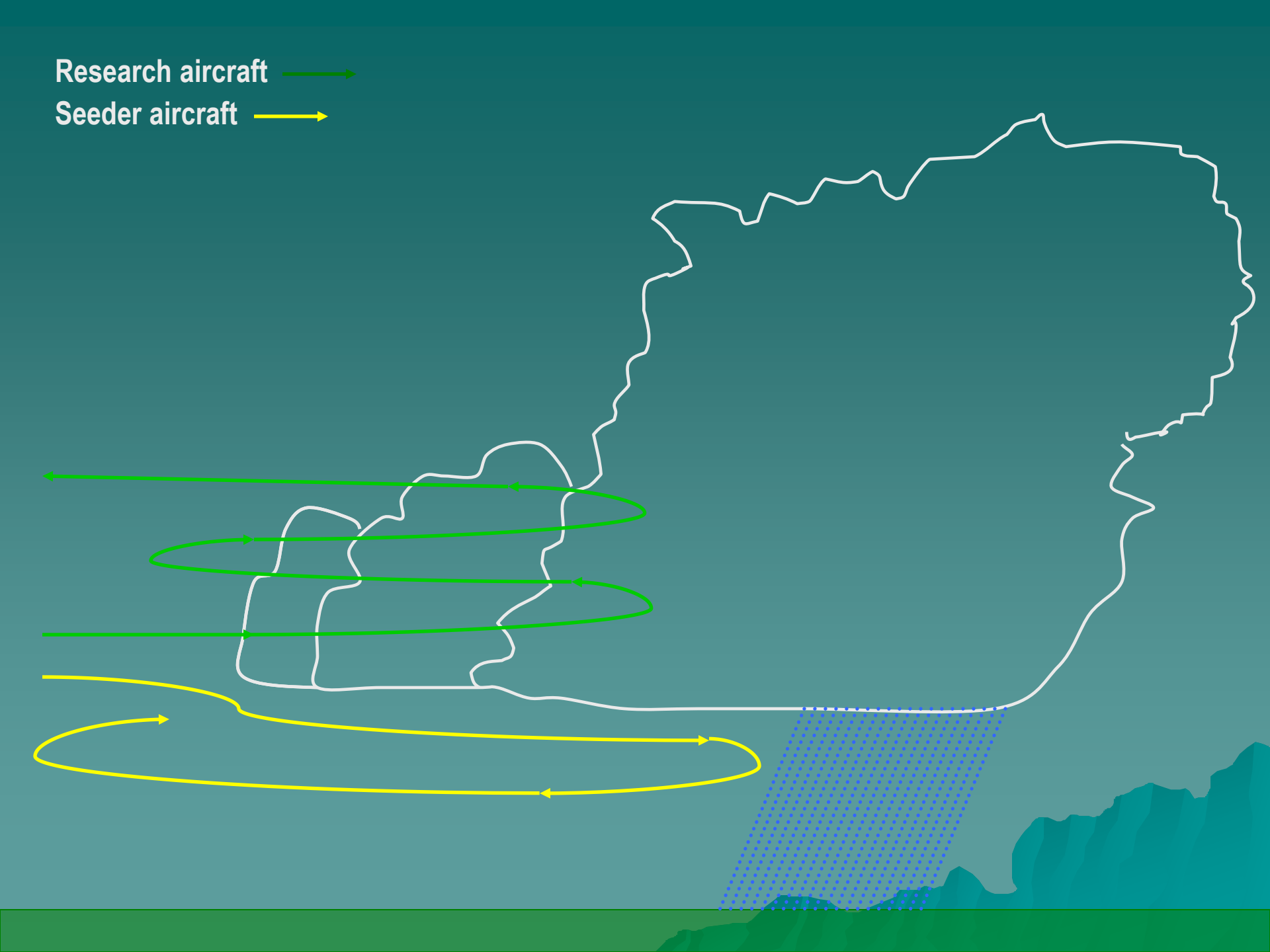
- **Multi-cell convective systems offer more promise for significant rain enhancement**

SOUTHWEST COOPERATIVE PROGRAM

Randomized Cloud-Seeding Research: USBR (1986-1990)

Target vs. control approach: 99 "Seeded" vs. 114 "No-seed"

- **Seeded cells yielded 2.63 times as much radar-estimated rainfall as non-seeded cells (significant at 5 percent level)**


Research aircraft
Seeder aircraft

Focused RESEARCH

- **TEXARC**

  Texas Exercise in Augmenting Rainfall thru Cloud seeding: NOAA (1994-1996)

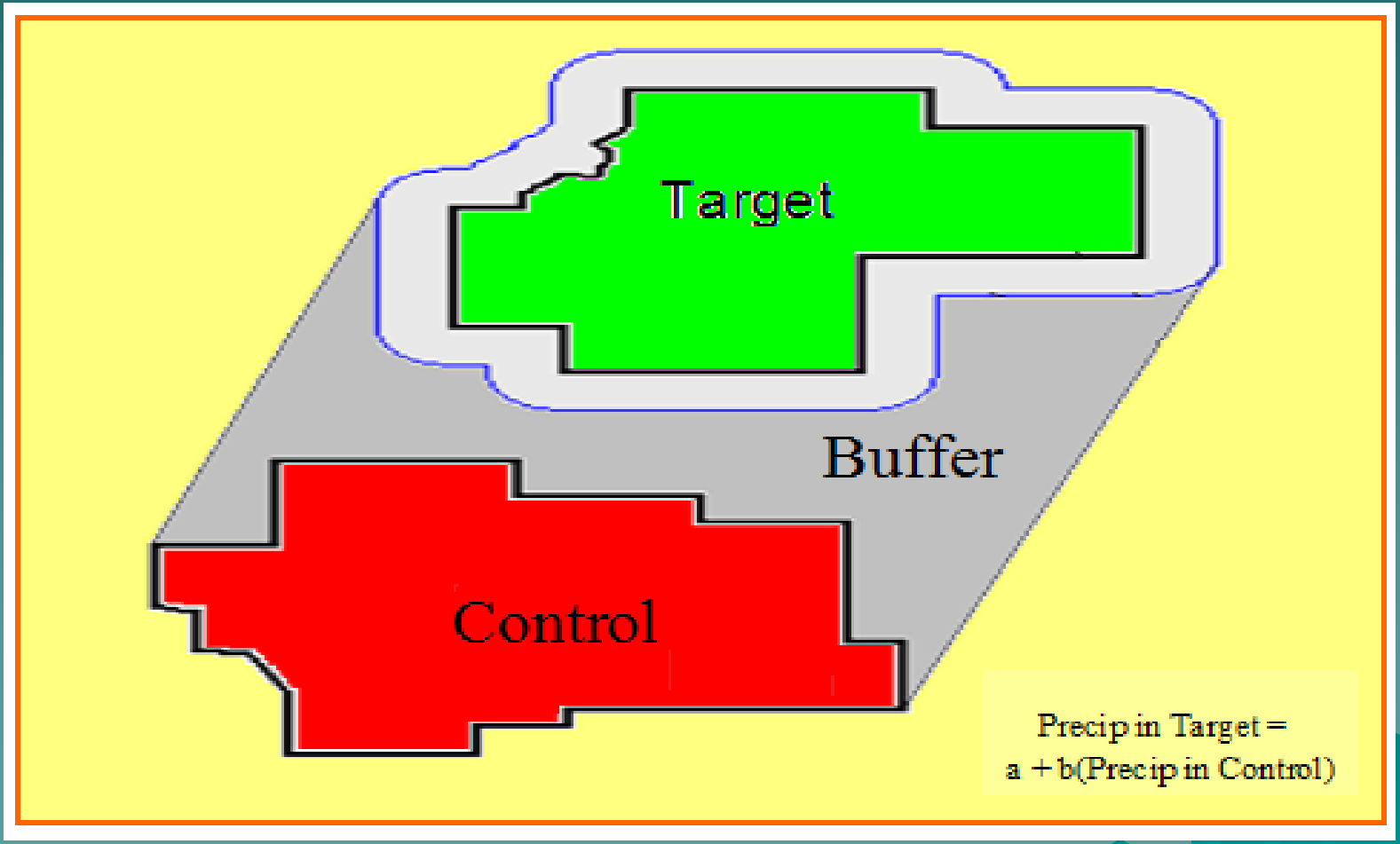
  - Cloud microphysical structure strongly dependent on CBTs
  - Timing and targeting are crucial

SPECTRA

Southern Plains Experiment in Cloud seeding of Thunderstorms for Rainfall Augmentation: USBR (2004-2006)

- Documented microphysical links between CCN and mechanisms responsible for forming precipitation
- Demonstrated that sizes of CCN are critical to formation of rainfall

Target and Control Method of Assessment



Origins of the Texas Program

- Drought of the ’90s the catalyst
- Collaboration of water districts
  - “Weather modification *associations*” established
  - Representation from each district (county)
- Public meetings to explain and reassure
- Aggressive campaign to inform elected officials

ROLE OF *Water Conservation Districts*

Progeny of the 1950s drought

Aims: To control draw-down from the aquifers
To facilitate recharge of the aquifers

Vested with *ad valorem* taxing authority

Governed by a Board whose members are elected

CONSERVATION DISTRICTS*, (Confirmed and Pending Confirmation)

1. Brazos Valley GCD - 11/8/2002
2. Brewster County GCD - 11/6/2001
3. Brush Country GCD - 11/3/2009
4. Central Texas GCD - 9/24/2005
5. Clear Fork GCD - 11/8/2002
6. Clearwater UWCD - 8/21/1989
7. Coastal Bend GCD - 11/6/2001
8. Coastal Plains GCD - 11/6/2001
9. Coke County UWCD - 11/4/1986
10. Colorado County GCD - 11/6/2007
11. Corpus Christi ASRCD - 6/17/2005
12. Cow Creek GCD - 11/8/2002
13. Crockett County GCD - 1/28/1991
14. Culberson County GCD - 8/2/1999
15. Duval County GCD - 7/25/2009
16. Edwards Aquifer Authority - 7/28/1996
17. Evergreen UWCD - 8/30/1965
18. Fayette County GCD - 11/8/2001
19. Fox Crossing Water District - 4/6/1996
20. Garza County UWCD - 11/6/1996
21. Gateway GCD - 8/5/2003
22. Glasscock GCD - 8/22/1991
23. Goliad County GCD - 11/6/2001
24. Gonzales County UWCD - 11/2/1994
25. Guadalupe County GCD - 11/14/1999
26. Hays Trinity GCD - 8/5/2005
27. Headwaters GCD - 11/5/1991
28. Hemphill County UWCD - 11/4/1967
29. Hickory UWCD No. 1 - 8/14/1982
30. High Plains UWCD No.1 - 9/29/1951
31. Hill Country UWCD - 8/8/1987
32. Hudspeth County UWCD No. 1 - 10/5/1987
33. Irion County WCD - 8/2/1965
34. Jeff Davis County UWCD - 11/2/1993
35. Kenedy County GCD - 11/2/2004
36. Kimble County GCD - 8/5/2002
37. Kinney County GCD - 1/13/2002
38. Lipan-Kickapoo WCD - 11/3/1987
39. Live Oak UWCD - 11/7/1989
40. Llano Estacado UWCD - 11/3/1998
41. Lone Star GCD - 11/6/2001
42. Lone Wolf GCD - 2/2/2002
43. Lost Pines GCD - 11/6/2002
44. Lower Trinity GCD - 11/7/2006
45. McMullen GCD - 11/6/2001
46. Medina County GCD - 8/26/1991
47. Menard County UWD - 8/14/1999
48. Mesa UWCD - 1/30/1990
49. Mesquite GCD - 11/6/1996
50. Mid-East Texas GCD - 11/6/2002
51. Middle Pecos GCD - 11/8/2002
52. Middle Trinity GCD - 8/4/2002
53. Neches & Trinity Valleys GCD - 11/6/2001
54. North Plains GCD - 1/2/1985
55. North Texas GCD - 12/1/2009
56. Northern Trinity GCD - 8/16/2007
57. Panhandle GCD - 1/21/1998
58. Panola County GCD - 11/6/2007
59. Pecan Valley GCD - 11/6/2001
60. Permian Basin UWCD - 8/21/1985
61. Pineywoods GCD - 11/6/2001
62. Plateau UWC and Supply District - 5/4/1974
63. Plum Creek CD - 5/1/1993
64. Post Oak Savannah GCD - 11/5/2002
65. Prairielands GCD - 5/1/2009
66. Presidio County UWCD - 8/31/1999
67. Real-Edwards C and R District - 5/30/1989
68. Red River GCD - 9/1/2009
69. Red Sands GCD - 11/5/2002
70. Refugio GCD - 11/6/2001
71. Rolling Plains GCD - 1/26/1999
72. Rusk County GCD - 8/5/2004
73. San Patricio County GCD - 8/13/2007
74. Sandy Land UWCD - 11/7/1989
75. Santa Rita UWCD - 8/19/1989
76. Saratoga UWCD - 11/7/1989
77. South Plains UWCD - 2/9/1992
78. Southeast Texas GCD - 11/22/2004
79. Southern Trinity GCD - 8/19/2009
80. Starr County GCD - 1/8/2007

Unconfirmed Groundwater Conservation Districts

- 81. Calhoun County GCD + &
- 99. Deep East Texas GCD + %
- 100. Reeves County GCD + %

+ Pending Election Results
& Created by the 83rd Legislature
% Created by the 82nd Legislature

Texas Water

0 25 50 75 100 Miles

STATE Support

Initial funding for 4 projects (1997)

State funds awarded on a 50-50 cost-share basis
Agreements made with *political subdivisions*

Allocation based on *acreage* per project (8 cents an acre)

Supplemental funding (1998-2003) for *new* projects

STATE Support

Appropriations for Rain Enhancement

			Projects
1997	$	550,000	4
1998-99		4,197,739	6
2000-01		4,904,626	8
2002-03		4,967,148	11
7-yr total	***$***	***14,619,513***	

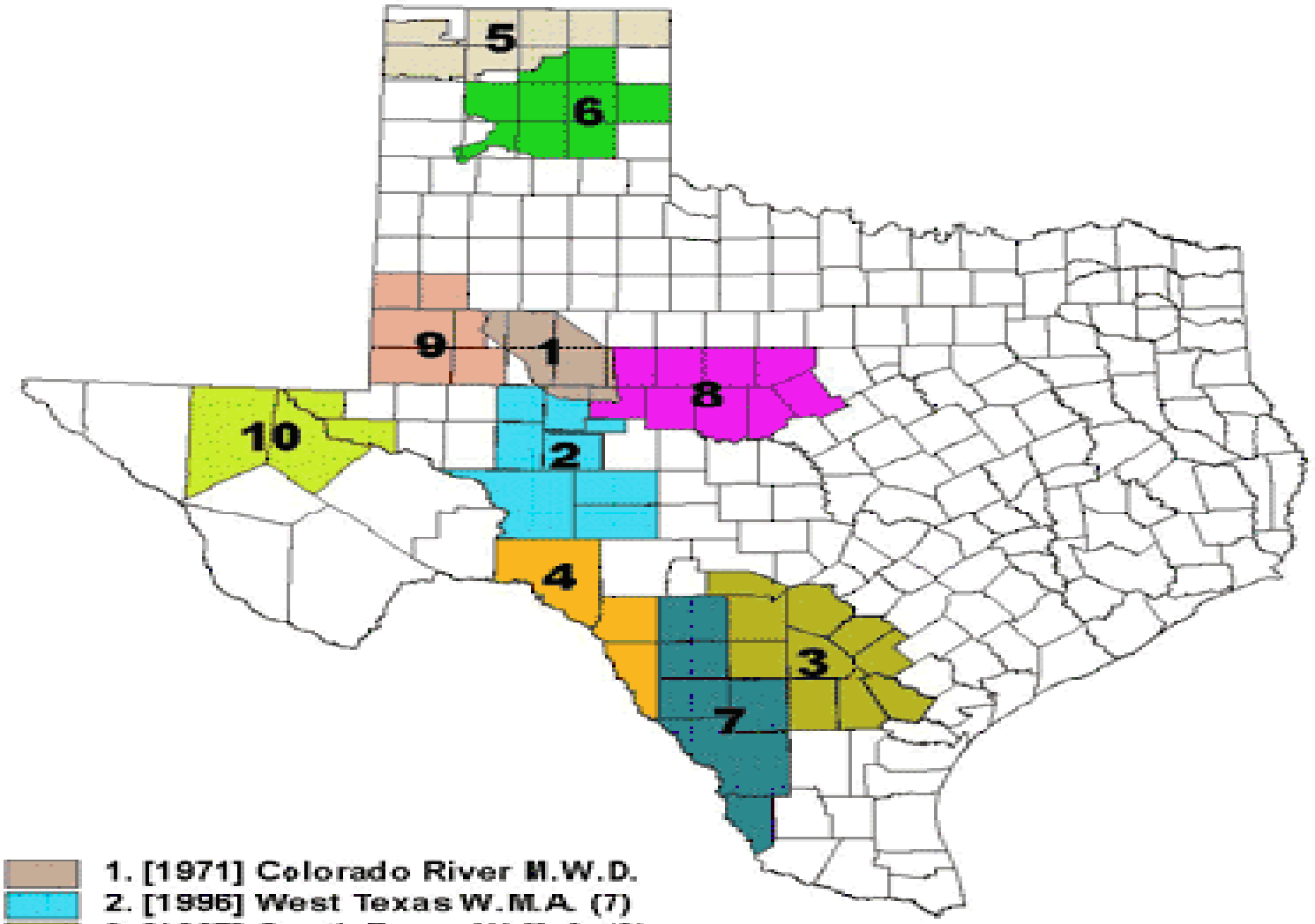
STATE Support

State appropriations $ 14.6 million

Expenses for Seeding Operations **13.066 million** **89%**
- Procurement of equipment
- Staff support
- Expendables

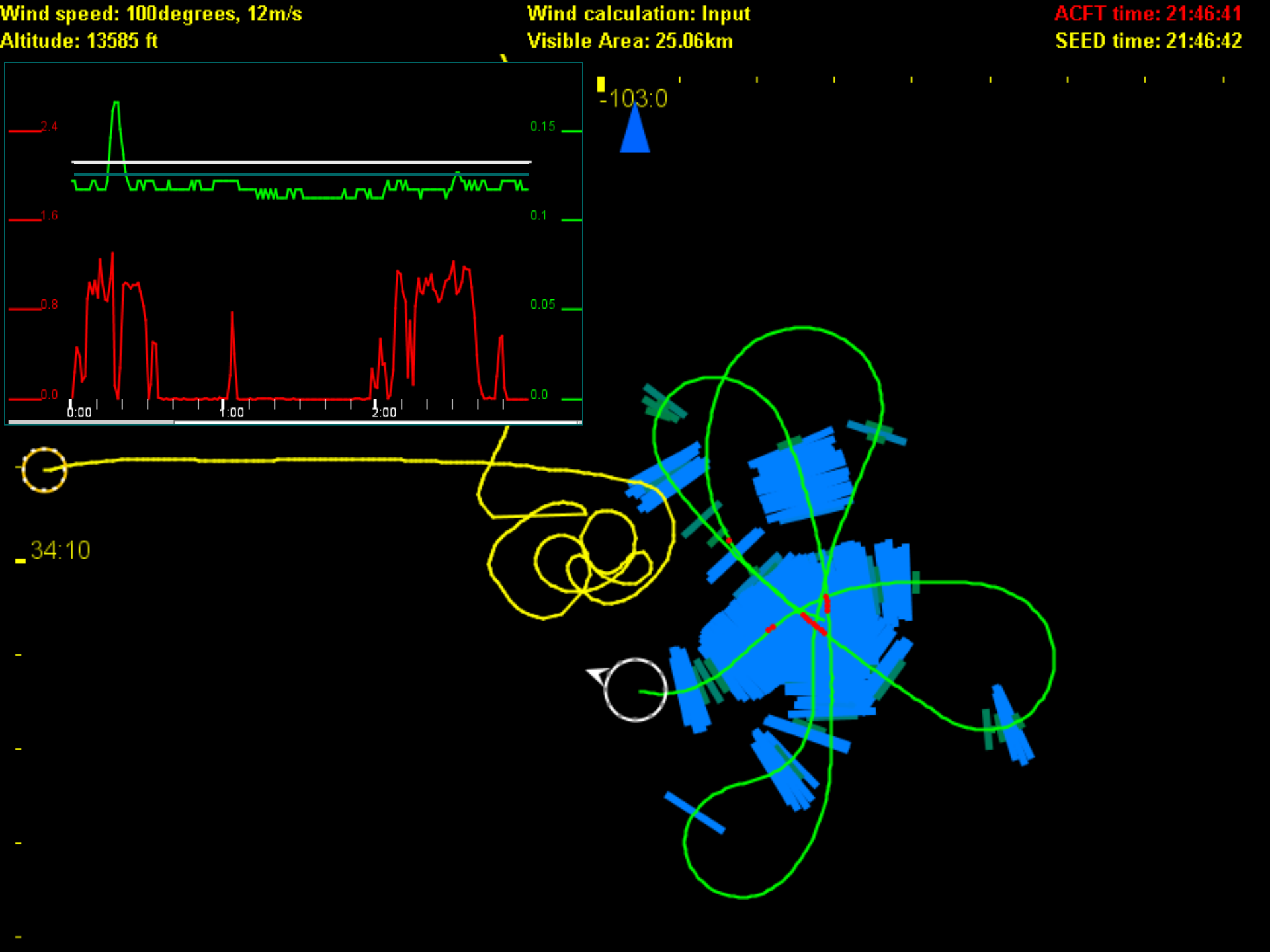
Technical Support **0.436 million** **3%**
- Public information, pilot training, flare development

Evaluation **1.098 million** **8%**
- Radar, satellite-based statistical assessments



1. [1971] Colorado River M.W.D.
2. [1996] West Texas W.M.A. (7)
3. [1997] South Texas W.M.A. (3)
4. [1998] Texas Border W.M.A.
5. [2000] North Plains G.C.D. (1)
6. [2000] Panhandle G.C.D. (1)
7. [1999] South West Texas R.E.A. (1)
8. [2001] West Central Texas W.M.A.
9. [2002] Southern Ogallala Aquifer Rain-Enhancement (3)
10. [2002] Trans-Pecos W.M.A.

[ ] Year began operations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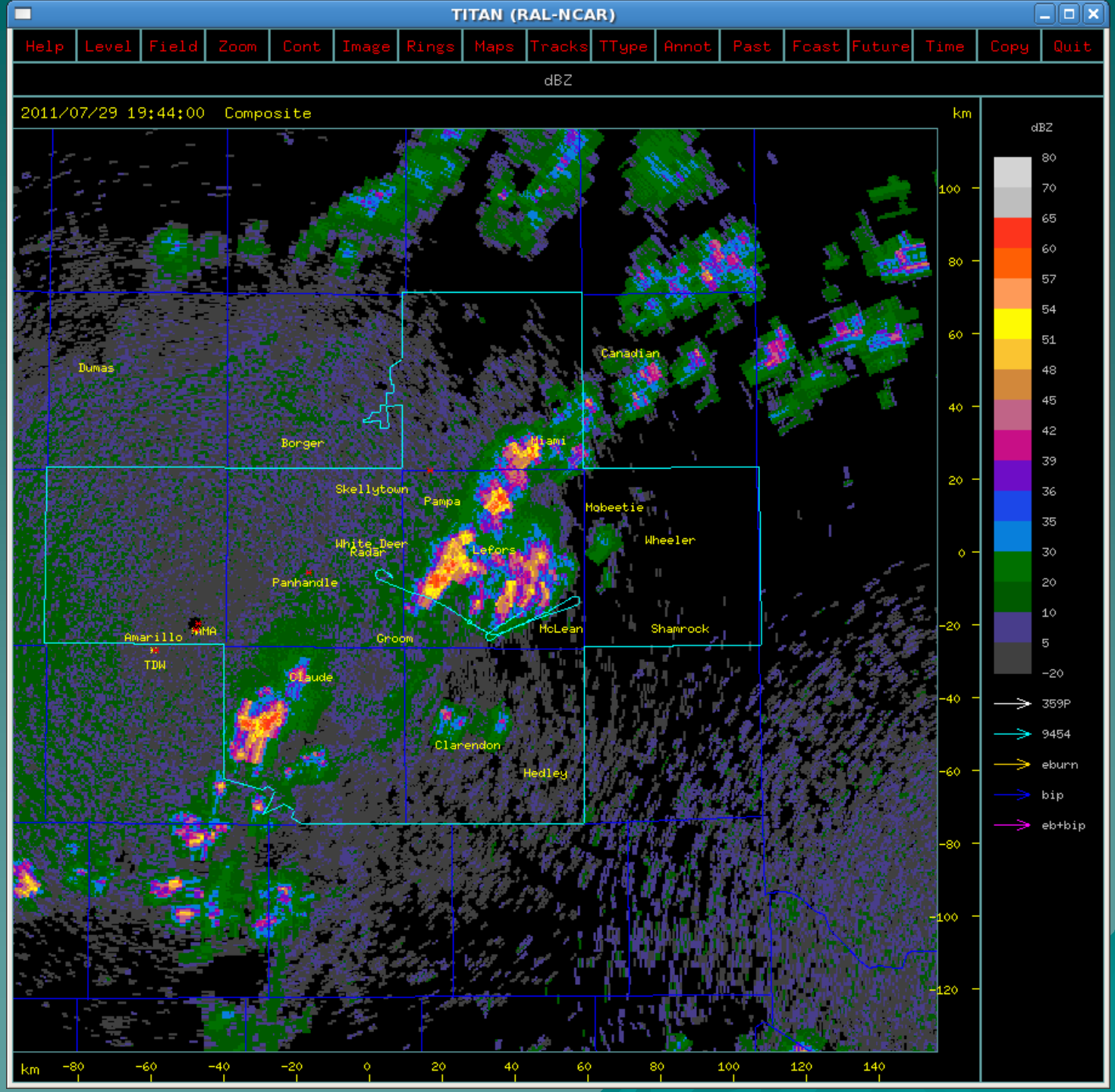
Altitude: 13585 ft
Wind calculation: Input
Visible Area: 25.06km
ACFT time: 21:46:41
SEED time: 21:46:42
-103:0
2.4
1.6
0.8
0.0
0.15
0.1
0.05
0.0
0:00
1:00
2:00
34:10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THE BOTTOM LINE

- **PROJECT SUMMARY (2004-12)**

Cumulus towers seeded each season (9-yr avg.) = 388

Single cell storms - 1634 (66%)

Multi-cell storms - 846 (33%)

Total number of *operational days* (avg.) = *165 days*

March 8 (2006, 2010) - October 18, 2010

Amount of seeding material = 4,099 flares per season

228 kg per season

THE BOTTOM LINE

Radar-based statistical assessment

(2004-2012)

Single-cell convective towers ONLY

Seeded vs. non-treated

DURATION	40 percent ***longer***
COVERAGE	35 percent ***greater***
CLOUD VOLUME	41 percent ***greater***
CLOUD TOP	**3 percent *higher***
CLOUD MASS	44 percent ***greater***
RAINFALL MASS	**111 percent *greater***

- **Real-time quantification of missed opportunities**
- **Estimates of seeding dosage: 80 IN per liter**

THE BOTTOM LINE

Estimated *increased* rain output from seeded (single-cell) storms

Avg. for 9-year period ('04-12) 146,019 acre-feet

Estimated cost of rainwater produced

Avg. for 9-year period $ 10.82 per acre foot

Estimated increased rain output for multi-cell storms:

Avg. 9-year period ('04-12): 1,833,415 acre-feet

Seedability

	La Nina	*Neutral*	El Nino	La Nina
	2008	***2009***	***2010***	***2011***
ONI	-0.8	-0.1	+0.8	-0.6
PGCD	29 events	32	41	26
MI	**-3.5**	**-3.3**	**-4.3**	**-3.6**
W TX	77 events	188	127	128
MI	**-4.4**	**-4.2**	**-4.5**	**-4.1**
SW TX	42 events	80	77	42
MI	**-3.3**	**-4.5**	**-4.2**	**-3.8**

"Continental" cloud conditions are more prevalent in La Nina seasons

--making them **less seedable with AgI**

Thank You for Your Attention